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# A COMPARISON OF THE SEASONAL ACTIVITY OF *PTEROSTICHUS* BEETLES (COLEOPTERA: CARABIDAE) IN A COMMERCIAL APPLE ORCHARD IN SONOMA COUNTY, CALIFORNIA

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*Abstract.*—Adults of the predatory *Pterostichus* beetles were trapped in a commercial orchard for two consecutive apple-growing seasons. *Pterostichus* (*Dysidius*) *lustrans* LeConte, *Pterostichus* (*Poecilus*) *cursitor* LeConte, and two *Pterostichus* (*Hypherpes*) species, were occasionally more active on the soil surface in plots under organic management of insect pests of apple, than in plots under conventional management. But, the mean number of individuals captured in replicated plots, between the two management schemes, was not significantly different on any collection date. Adults of *P. lustrans,* the predominant species of *Pterostichus* inhabiting the orchard, were most active on the soil surface during May, June, and July 1991. In the 1992 season, *P. lustrans* were most active during June and July, *P.* (*Hypherpes*) spp. were most active during June, and *P. cursitor* were most active during July. The activity of *Pterostichus* beetles may coincide with the time interval in which fifth-instar *Cydia pomonella* (L.) (codling moth) larvae wander on the ground prior to pupation.

*Key Words.*—Insecta, Coleoptera, Carabidae, *Pterostichus,* predators

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Carabid beetles are major components of the predator assemblages in managed and unmanaged ecosystems (Kulman 1974, Luff 1987). Many species are predators of insect pests in agroecosystems (Allen 1979, Clark et al. 1994). For example, in apple orchards, adult carabids are important predators of apple maggot, *Rhagoletis pomonella* (Walsh) (Allen & Hagley 1990) and codling moth, *Cydia pomonella* (L.) (Hagley et al. 1982, Hagley & Allen 1988). Several *Pterostichus* species are the most effective carabid predators of the codling moth (Riddick & Mills 1994). However, carabid predation alone cannot reduce codling moth populations to a level sufficient to prevent economic damage to fruit and eliminate the use of insecticides.

Previous research has determined the effect of organophosphate insecticides on carabid populations in orchards. Phosmet sprays reduced the numbers of *Amara* spp. and *Harpalus affinis* (Schrank) adults captured in pitfall traps in an apple orchard in Ontario, Canada; but not the number of *Pterostichus melanarius* (Illiger) adults captured (Hagley et al. 1980). In the laboratory, phosmet killed *Amara* spp. and *H. affinis,* but not *P. melanarius* (Hagley et al. 1980).

The use of a formulation of codling moth granulosis virus, a microbial insecticide, was correlated with enhanced surface activity of *Harpalus pensylvanicus* DeGeer adults in July, but not with the activity of *Pterostichus* (*Hypherpes*) sp. adults in an apple orchard in Contra Costa County, California (Riddick & Mills

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1995). This suggests that some carabid species can become more useful in orchards that are treated with microbial insecticides for the suppresion of insect pests.

The objective of this research was to compare the seasonal activity of *Pterostichus* beetles in replicated plots of a commercial apple orchard under conventional or organic apple production. It is essential to determine the activity patterns of the *Pterostichus* species so that their potential as control agents of insects pests can be evaluated.

## Materials and Methods

The study site was a commercial apple orchard (Jewell Ranch) located in the coastal region of northern California (Sonoma County), near Sebastopol, a major apple growing district. The orchard was dry-farmed and contained standard trees of Gravenstein, Red, and Golden Delicious varieties. The 6.5 ha experimental section of this ≈20 ha orchard was surrounded by non-experimental sections of trees, which were treated with organophosphate insecticides, on three sides and a residence on the remaining side. The experimental section was subdivided into eight plots, which were originally designated in 1989 to monitor the effect of various insecticides on the codling moth. Each 0.81 ha (2 acre) plot was comprised of 9 rows of trees and each containing ≈20 trees. The average distance between trees in a row was 7.3 m, and the average distance from the adjacent row was 6.4 m.

Details of the pest management practices in the commercial orchard have been reported elsewhere (Vossen et al. 1994). During the 1991 and 1992 apple growing seasons, synthetic organophosphate or granulosis virus insecticides (designed to suppress the neonate stage of *C. pomonella*), were sprayed onto trees in replicated plots. Conventional plots contained trees that were sprayed with organophosphate insecticides and herbicides, whereas organic plots contained trees that were sprayed with microbial insecticides and in which mating disruption pheromones (in dispensers) were used.

Each treatment (conventional or organic) plot was replicated four times for a total of eight 0.81 ha plots. Both treatments were systematically alternated within the experimental section of the orchard such that the first replicate plot of the conventional treatment was proceeded by the first replicate plot of the organic treatment. Thus, four replicate plots of the conventional treatment were alternated, spatially, with four replicate plots of the organic treatment. Although this design lacked control plots, it provided a realistic method of comparing the activity of carabid beetles in a commercial setting.

Insecticide treatments were applied during *C. pomonella* egg-hatch periods, predicted from degree-day models (Pickel et al. 1986). Two to three generations of *C. pomonella* per season have been common in northern California. In the 1991 season, chlorpyrifos (Lorsban®) was sprayed in the conventional plots on 14 May at a rate of 2.8 kg/ha and on 7 June at a rate of 3.4 kg/ha, and phosmet (Imidan®) was sprayed on 9 July at a rate of 5.75 kg/ha. In the organic plots, codling moth granulosis virus (CMGV/UCB.87) was sprayed on 11, 29 May; 13, 20, 27 July; and on 3, 10, 17, 24 August in applications of $1.5 \times 10^{14}$ granular inclusion bodies per ha, plus 0.45 liters/ha of NuFilmP sunscreen, and 5.7 kg/ha of DriFlo molasses. Each formulation was combined with 378.5 liters of tap water, then applied with a fan air-blast sprayer. In the 1992 season, chlorpyrifos was sprayed again in the identical conventional plots of the previous season on 23

April (rate of 3.4 kg/ha) and phosmet on 2 June (rate of 5.75 kg/ha). Codling moth granulosis virus was sprayed in the identical organic plots on 28 April and 15 May as described above.

Early in the season 1991–1992, the herbicide paraquat was used to suppress weed growth at the base of the tree trunks in the conventional plots, but a hand hoe was used to remove the weeds in the organic plots. Mating disruption pheromones in dispensers (Isomate C) were positioned on trees in the organic and conventional plots on 23 Mar 1992 and again on 8 Jun 1992 at a rate of 1000 per ha.

The soil type in the commercial orchard is a Goldridge fine sandy-loam. The soil was disked, and the remaining resident vegetation was removed at the beginning of the apple growing season, in mid- to late April. After the end of the season in October or November, the soil was cultivated and a cover crop of bell beans (*Vicia faba* L.) and vetch (*Vicia* spp.) was seeded in all plots.

The seasonal activity of adult *Pterostichus* beetles inhabiting the commercial orchard was compared between the treatment plots, with pitfall traps. Pitfall trapping has become a standard technique for sampling carabids (Morrill 1975, Halsall & Wratten 1988). Trap catch may estimate the activity of adult carabids on the soil surface as well as reflect the density of carabid populations (Hokkanen & Holopainen 1986). Traps were plastic cups (473 ml), with a 9 cm diameter opening, which were sunk into the ground so that the rim was flush with the soil surface. Leaf litter within 20 cm of the perimeter of each trap was removed and the soil smoothed to prevent the litter from impeding the movement of carabids around the traps (Greenslade 1964, Powell et al. 1985). Traps were filled to the one-quarter mark with a solution of water and liquid detergent, which reduced the surface tension of the water causing captured beetles to sink to the bottom of the trap. A preservative was not used in the traps because of the risk that it would alter the catch and sex ratio of the trapped species (Holopainen 1992).

Six pitfall traps were positioned in the central row of trees in each of the eight plots in the 1991 season. The distance between traps was not recorded, but traps were two to three trees apart within the same row. Traps were in place for consecutive days during each of five sampling periods in 1991, 30 April–7 May, 4–11 June, 3–9 July, 30 July–9 August, and 4–11 September. In the 1992 season, three traps were positioned in the identical tree rows of the previous season. Traps were in place for consecutive days during each of five sampling periods, 11–14 May, 5–8 June, 7–10 July, 28–31 July, and 18–21 August. Samples were collected on the last day of each sampling period.

Trapped beetles of the genus *Pterostichus* were sorted to species or species groups in the laboratory. *Pterostichus* beetles were selected because of their potential as effective predators of codling moth (Riddick & Mills 1994). The species counted were *Pterostichus* (*Dysidius*) *lustrans* LeConte, *Pterostichus* (*Poecilus*) *cursitor* LeConte, and two *Pterostichus* (*Hypherpes*) species, namely, *Pterostichus californicus* (Dejean) and *Pterostichus castanipes* (Ménétriés) which are morphologically similar, and not readily distinguishable at the time that this research was undertaken. *Pterostichus californicus* and *P. castanipes* adults have been collected in California only. *Pterostichus cursitor* adults have been collected in California and Oregon, and *P. lustrans* adults have been collected in British Columbia, south to California and east to New Mexico and Colorado (Bousquet & Larochelle 1993).

Trap data were converted to mean number of *Pterostichus* species per tree row per trap per day in each treatment plot. All means were log-transformed before subjection to the analysis of variance (ANOVA). Treatment means were considered significant if $P \leq 0.05$. All statistical analyses were performed with Statgraphics (STSC) software. Voucher specimens are located at the Laboratory of Biological Control, University of California, Berkeley, and the Department of Entomology, University of Maryland, College Park.

## Results

A total of 577 adult carabids were captured in pitfall traps in the 1991 apple growing season. *Pterostichus lustrans* represented 22.2%, *Pterostichus cursitor* represented 11.8%, and the two *Pterostichus* (*Hypherpes*) species represented a combined 11.3% of the total adult carabids. In the 1992 season, a total of 638 adult carabids were captured, and *P. lustrans* represented 10.3%, *P. cursitor,* 6.0%; and *P.* (*Hypherpes*) spp., 2.3%.

The seasonal activity of all adult *Pterostichus* species was compared between the conventional and organic treatment plots. There was no significant difference in total beetle activity on the soil surface on any collection date between treatments in the 1991 or 1992 season (Tables 1 and 2). Individually, *P. lustrans* was most active during early May, June, and July, but no clear pattern was discernable for *P. cursitor* or *P.* (*Hypherpes*) spp. (Table 1). In 1992, *P. lustrans* adults were most active during early June and early July, whereas *P. cursitor* adults were most active during early July, and *P.* (*Hypherpes*) spp. adults were most active during early June (Table 2).

## Discussion

During the first two sampling periods (7 May, 11 June) in the 1991 season, *P. lustrans* adults were almost significantly more active in the organic plots than in the conventional plots of the commercial orchard. Apparently, a number of these beetles avoided contact with chlorpyrifos, phosmet or paraquat on the ground in the conventional plots. Chlorpyrifos has been shown to have no significant effect on the activity of *Pterostichus* spp. adults in treated fields of grass in comparison to untreated fields (Asteraki et al. 1992) but it is toxic to *P. melanarius* and *Pterostichus chalcites* Say adults (Bale et al. 1992, Reed et al. 1992). Phosmet did not reduce the activity of *P. melanarius* in an apple orchard, nor did it kill *P. melanarius* in the laboratory (Hagley et al. 1980).

Paraquat was applied in the conventional plots, but not in the organic plots. Brust (1990) found that the activity of *Pterostichus* sp. adults was reduced for up to 28 d after paraquat had been sprayed.

Codling moth granulosis virus and mating disruption pheromone did not appear to affect *Pterostichus* beetle activity. The seasonal activity of *P.* (*Hypherpes*) spp. adults in an organic managed section of a commercial apple orchard in Contra Costa County was not altered by these alternative methods of suppressing codling moth (Riddick & Mills 1995). In this study a complete randomized design was used and each treatment (formulations of granulosis virus, *Bacillus thuringiensis* Berliner plus oil, oil alone, no-spray control) was replicated three times. In the present study, a no-spray treatment was not allowable. Consequently, these data

Table 1. Seasonal activity of *Pterostichus* beetles in organic and conventional plots on collection dates in the commercial orchard, 1991 season.

| Treatment | Mean (±SEM) no. of beetles per tree row per trap per day | | | | |
|---|---|---|---|---|---|
| | 7 May | 11 June | 9 July | 9 Aug. | 11 Sept. |
| *P. lustrans* | | | | | |
| Organic | 0.24 (0.09) | 0.17 (0.07) | 0.12 (0.04) | 0.02 (0.02) | 0.01 (0.01) |
| Conven. | 0.06 (0.03) | 0.01 (0.01) | 0.07 (0.05) | 0.02 (0.01) | 0.01 (0.01) |
| F; *P*[a] | 4.20; 0.09 | 4.99; 0.77 | 0.87; 0.40 | 0.48; 0.52 | 0.00; 1.00 |
| *P. cursitor* | | | | | |
| Organic | 0.10 (0.04) | 0.03 (0.02) | 0.06 (0.03) | 0.08 (0.03) | 0.00 (0.00) |
| Conven. | 0.02 (0.01) | 0.01 (0.01) | 0.03 (0.01) | 0.05 (0.05) | 0.00 (0.00) |
| F; *P* | 3.71; 0.10 | 0.48; 0.52 | 0.90; 0.39 | 0.40; 0.55 | —; — |
| *P.* (*Hypherpes*) spp. | | | | | |
| Organic | 0.01 (0.01) | 0.09 (0.07) | 0.10 (0.04) | 0.03 (0.01) | 0.05 (0.01) |
| Conven. | 0.00 (0.00) | 0.03 (0.01) | 0.03 (0.03) | 0.01 (0.01) | 0.03 (0.02) |
| F; *P* | 3.00; 0.13 | 0.74; 0.43 | 2.32; 0.18 | 2.07; 0.20 | 0.82; 0.41 |

[a] Degrees of freedom = 1, 6; and 8 plots were sampled on each collection date. —; — = F and *P* values not reported because no beetles were captured.

cannot reveal whether *Pterostichus* activity in unsprayed plots differed from that observed in the conventional or organic managed plots.

*Pterostichus lustrans* adults were the most numerous of the *Pterostichus* beetles in the orchard. The adults were most active on the soil surface during May, June, and July 1991, and during June and July of 1992. Similar activity was observed for *P. lustrans* in a nearby orchard that was not sprayed with pesticides (Riddick, unpublished data). This pronounced activity may correlate with an increased availability of suitable prey. The activity of *Pterostichus* beetles may coincide with the time that *C. pomonella* larvae are wandering on the ground in search of pupation sites. First generation larvae leave fruit during May or June in orchards in California (Pickel et al. 1986), and thereafter become vulnerable to predation by *Pterostichus* beetles on the ground.

The nightly rate of predation of tethered *C. pomonella* fifth-instar larvae by carabids was 60% in early June in an organic managed block of an apple orchard of semi-dwarf trees in Brentwood, California (Riddick & Mills 1994). *Pterostichus* (*Hypherpes*) sp. (possibly *P. californicus*) adults were one of the most active carabid species on the soil surface during this time interval. (Note that *P. lustrans* and *P. cursitor* were very rare in this Brentwood orchard.) When *Pterostichus* beetles are active and abundant, their predation may help reduce the density of the upcoming second generation of *C. pomonella* in modern orchards. But this assumption is valid only when *Pterostichus* adults readily locate and capture unrestricted fifth-instars on the ground.

The reduced activity of *P. lustrans* in August in the Sebastopol orchard may have resulted from inadequate moisture and intolerable temperatures at the soil surface. The climate in the Sebastopol region is Mediterranean, characterized by hot, dry summers and mild, wet winters (Altieri & Schmidt 1986). The lack of ideal conditions for activity may have influenced the adults to remain beneath the surface. In contrast, the reduced activity in August could have resulted from

Table 2. Seasonal activity of *Pterostichus* beetles in organic and conventional plots on collection dates in the commercial orchard, 1992 season.

| Treatment | Mean (±SEM) no. of beetles per tree row per trap per day | | | | |
|---|---|---|---|---|---|
| | 14 May | 8 June | 10 July | 31 July | 21 Aug. |
| *P. lustrans* | | | | | |
| Organic | 0.03 (0.03) | 0.64 (0.39) | 0.47 (0.11) | 0.05 (0.03) | 0.00 (0.00) |
| Conven. | 0.14 (0.05) | 0.00 (0.00) | 0.22 (0.08) | 0.03 (0.03) | 0.00 (0.00) |
| F; *P*[a] | 3.38; 0.12 | 3.77; 0.10 | 3.44; 0.11 | 0.43; 0.54 | —; — |
| *P. cursitor* | | | | | |
| Organic | 0.00 (0.00) | 0.03 (0.03) | 0.58 (0.19) | 0.05 (0.03) | 0.00 (0.00) |
| Conven. | 0.00 (0.00) | 0.00 (0.00) | 0.25 (0.08) | 0.03 (0.03) | 0.08 (0.05) |
| F; *P* | —; — | 1.00; 0.36 | 2.27; 0.18 | 0.43; 0.54 | 2.51; 0.16 |
| *P.* (*Hypherpes*) spp. | | | | | |
| Organic | 0.05 (0.05) | 0.25 (0.08) | 0.03 (0.03) | 0.00 (0.00) | 0.00 (0.00) |
| Conven. | 0.00 (0.00) | 0.08 (0.05) | 0.05 (0.05) | 0.00 (0.00) | 0.00 (0.00) |
| F; *P* | 1.00; 0.36 | 2.63; 0.16 | 0.18; 0.69 | —; — | —; — |

[a] Degrees of freedom = 1, 6; and 8 plots were sampled on each collection date. —; — = F and *P* values not reported because no beetles were captured.

increased growth of native vegetation in the commercial orchard. Although the vegetation was sparse in all plots, its presence could have obstructed or altered the speed of movement of *P. lustrans,* especially if these beetles investigated the base of plants when searching for potential prey.

In conclusion, although the activity of *Pterostichus* beetles was not significantly different between the conventional and organic treatments at any sampling period, the spraying of conventional pesticides must be minimized in the spring, the season of heightened activity of these carabids.

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